# PATENT SPECIFICATION

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(19)

## (54) IMPROVEMENTS IN OR RELATING TO ALUMINIUM ALLOY WIRE

(71) We, SOUTHWIRE COMPANY, a Corporation of the State of Georgia, United States of America, of 126, Fertilla Street, Carollton, Georgia, United States of America, do hereby declare the invention for which we pray that a Patent may be granted to us and the method by which it is to be performed, to be particularly described in and by the following statement:

This invention relates to an aluminum alloy wire suitable for use as an electrical conductor and to a process for preparing aluminum alloy wire and more particularly concerns an aluminum alloy conductor having an acceptable electrical conductivity and improved elongation, bendability and tensile strength.

The use of various aluminum alloy wires (conventionally referred to as EC wire) as general purpose conductors of electricity is well established in the art. In addition, aluminum alloy wires have been used as wire windings for electromagnets, as multifilament conductors of electricity, and as telephone cable. The commercial alloys employed therein characteristically have conductivities of at least sixty-one percent (61%) of the International Annealed Copper Standard (hereinafter sometimes referred to as IACS) and chemical constituents consisting of a substantial amount of pure aluminum and small amounts of conventional impurities such as silicon, vanadium, iron, manganese, zinc, boron and titanium. The physical properties of prior aluminum alloy wire have proven less than desirable in many applications. Generally, desirable percent elongations have been obtained only at less than desirable tensile strengths and desirable tensile strengths have been obtainable only at less than desirable percent elongations. In addition, the bendability and fatigue resistance of prior aluminum alloy wires has been so low that the prior wire has been generally unsuitable for many otherwise desirable applications.

Thus, it becomes apparent that a need has arisen within the industry for an aluminum alloy conductor which has both improved percent elongation and improved tensile strength, and also possesses an ability to withstand numerous bends at one point and to resist fatiguing during use of the conductor. Therefore, it is an object of the present invention to provide an aluminum alloy conductor of acceptable conductivity and improved physical properties such that the conductor may be used in new applications. Another object of the present invention is to provide an aluminum alloy conductor having novel properties of increased ultimate elongation and tensile strength, improved bendability and fatigue resistance, and acceptable electrical conductivity. These and other objects, features and advantages of the present invention will become apparent to those skilled in the art from a consideration of the following detailed description of the invention.

According to the present invention there is provided a Wrought aluminum alloy wire having a minimum conductivity of sixty-one percent IACS consisting essentially of from 0.30 to less than 0.45 weight percent iron; 0.015 to 0.15 weight percent silicon; from 0.0001 to less than 0.05 weight percent each of trace elements selected from the group consisting of vanadium, manganese, zinc, boron, and titanium, and the remainder aluminum, said alloy containing from 0.004 to 0.15 total weight percent trace elements and substantially evenly distributed $FeAl_3$ inclusions having a particle size of less than 2000 Angstrom Units.

The invention also includes aluminum alloy wire having a minimum conductivity of sixty-one percent IACS containing substantially evenly distributed $FeAl_3$ inclusions

in a concentration produced by the presence of 0.30 to less than 0.45 weight percent iron in an alloy mass consisting essentially of 0.015 to 0.15 weight percent silicon; conventional impurities; and the remainder aluminum; a majority of said $FeAl_3$ inclusions having a particle size of less than 2,000 angstrom units.

The invention also provides a process for preparing an aluminum alloy wire in accordance with the present invention having an electrical conductivity of at least 61 per cent IACS comprising the steps of:

a. Alloying from 0.30 to less than 0.45 weight percent iron, 0.015 to 0.15 weight percent silicon, and from 0.0001 to 0.05 weight percent each of trace elements selected from the group consisting of vanadium, manganese, zinc, boron and titanium, and the remainder aluminum; the total weight percent of trace elements being 0.004 to 0.15 weight percent;

b. Casting the alloy into a continuous bar in a moving mold formed by a groove in the periphery of a casting wheel and an endless belt lying adjacent the groove along a portion of the periphery of the wheel;

c. Hot-working the bar substantially immediately after casting while the bar is in substantially that condition as cast by rolling the bar to obtain a continuous aluminum alloy rod having a conductivity of less than 61% IACS;

d. Drawing the rod with no preliminary or intermediate anneals to form wire having a conductivity of less than 61% IACS; and

e. Annealing or partially annealing the wire to obtain wire having a conductivity of at least 61% IACS and $FeAl_3$ inclusions with a particle size of less than 2,000 angstrom units.

Preferably, from 0.015 to 0.15 weight percent silicon is employed in the present alloy. Preferably, the ratio between the percentage iron and the percentage silicon is 1.99:1 or greater. Thus, if the present aluminum alloy contains an amount of iron within the low area of the present range for iron content, the percentage of aluminum must be increased rather than increasing the percentage of silicon outside the ratio limitation previously specified. It has been found that properly processed wire, having aluminum alloy constituents which fall within the above-specified ranges, possesses acceptable electrical conductivity, improved tensile strength and ultimate elongation; and in addition, has a novel unexpected property of surprisingly increased bendability and fatigue resistance.

The present aluminum alloy is prepared by initially melting and alloying commercial aluminum with the necessary amounts of iron or other constituents to provide the requisite alloy for processing. Typical impurities or trace elements are also present within the melt in trace quantities such as between 0.0001 and 0.05 weight percent each, with a total content of trace impurities ranging between 0.004 and 0.15 weight percent. Of course, when adjusting the amounts of trace elements, due consideration must be given to the conductivity of the final alloy since some trace elements affect conductivity more severely than others. The typical trace elements include vanadium, manganese, zinc, boron and titanium. If the content of titanium is relatively high (but still quite low when compared to the aluminum, iron and silicon content), small amounts of boron may be added to tie-up the excess titanium and keep it from reducing the conductivity of the wire.

After alloying in one preferred embodiment, the melted aluminum composition is continuously cast into a continuous bar. The bar is then hot-worked in substantially that condition in which it is received from the casting machine. A typical hot-working operation comprises rolling the bar in a rolling mill substantially immediately after being cast into a bar. Other methods for preparation of the present conductor may also be employed so long as the cast bar or ingot is hot-worked to a rod product without reheating.

One example of a continuous casting and rolling operation, capable of producing continuous rod as specified in this application, is as follows:

A continuous casting machine serves as a means for solidifying the molten aluminum alloy metal to provide a cast bar that is conveyed in substantially the condition in which it solidified from the continuous casting machine to the rolling mill, which serves as a means for hot-forming the cast bar into rod or another hot-formed product in a manner which imparts substantial movement to the cast bar along a plurality of angularly disposed axes.

The continuous casting machine is of conventional casting wheel type having a casting wheel with a casting groove partially closed by an endless belt supported by the casting wheel and an idler pulley. The casting wheel and the endless belt cooperate to provide a mold into one end of which molten metal is poured to solidify and from the other end of which the cast bar is emitted in substantially that condition in which it solidified.

The rolling mill is of conventional type having a plurality of roll stands arranged to hot-form the cast bar by a series of deformations. The continuous casting machine and the rolling mill are positioned relative to each other so that the cast bar enters the rolling mill substantially immediately

after solidification and in substantially that condition in which it solidified. In this condition, the cast bar is at a hot-forming temperature within the range of temperatures for hot-forming the cast bar at the initiation of hot-forming without heating between the casting machine and the rolling mill. In the event that it is desired to closely control the hot-forming temperature of the cast bar within the conventional range of hot-forming temperatures, means for adjusting the temperature of the cast bar may be placed between the continuous casting machine and the rolling mill without departing from the inventive concept disclosed herein.

The roll stands each include a plurality of rolls which engage the cast bar. The rolls of each roll stand may be two or more in number and arranged diametrically opposite from one another or arranged at equally spaced positions about the axis of movement of the cast bar through the rolling mill. The rolls of each roll stand of the rolling mill are rotated at a predetermined speed by a power means such as one or more electric motors and the casting wheel is rotated at a speed generally determined by its operating characteristics. The rolling mill serves to hot-form the cast bar into a rod of a cross-sectional area substantially less than that of the cast bar as it enters the rolling mill.

The peripheral surfaces of the rolls of adjacent roll stands in the rolling mill change in configuration; that is, the cast bar is engaged by the rolls of successive roll stands with surfaces of varying configuration, and from different directions. This varying surface engagement of the cast bar in the roll stands functions to knead or shape the metal in the cast bar in such a manner that it is worked at each roll stand and also to simultaneously reduce and change the cross-sectional area of the cast bar into that of the rod.

As each roll stand engages the cast bar, it is desirable that the cast bar be received with sufficient volume per unit of time at the roll stand for the cast bar to generally fill the space defined by the rolls of the roll stand so that the rolls will be effective to work the metal in the cast bar. However, it is also desirable that the space defined by the rolls of each roll stand not be overfilled so that the cast bar will not be forced into the gaps between the rolls. Thus, it is desirable that the rod be fed toward each roll stand at a volume per unit of time which is sufficient to fill, but not overfill, the space defined by the rolls of the roll stand.

As the cast bar is received from the continuous casting machine, it usually has one large flat surface corresponding to the surface of the endless band and inwardly tapered side surfaces corresponding to the shape of the groove in the casting wheel. As the cast bar is compressed by the rolls of the roll stands, the cast bar is deformed so that it generally takes the cross-sectional shape defined by the adjacent peripheries of the rolls of each roll stand.

The aluminum alloy rod prepared according to the present invention has a conductivity of less than 61% IACS. If the conductivity of the rod exceeds 61% IACS, then the processing steps of the present invention have not been followed and the rod product should be scrapped. The low conductivity of the rod is very interesting since in conventional processes it is customary for the rod product to have a conductivity in excess of 61% IACS.

The continuous rod produced by the casting and rolling operation is then processed without annealing or reheating in a reduction operation designed to produce continuous wire of various gauges. The unannealed rod (i.e., as rolled to f temper) is cold drawn through a series of progressively constricted dies, without intermediate anneals, to form a continuous wire of desired diameter. At the conclusion of this drawing operation, the alloy wire will have an excessively high tensile strength and an unacceptably low ultimate elongation, plus a conductivity below that which is industry accepted as the minimum for an electrical conductor, i.e., sixty-one percent (61%) of IACS. The wire is then annealed or partially annealed to obtain a desired tensile strength and cooled. At the conclusion of the annealing operation, it is found that the annealed alloy wire has the properties of acceptable conductivity and improved tensile strength together with unexpectedly improved percent ultimate elongation and surprisingly increased bendability and fatigue resistance as specified previously in this application. The annealing operation may be continuous as in resistance annealing, induction annealing, convection annealing by continuous furnaces or radiation annealing by continuous furnaces, or, preferably, may be batch annealed in a batch furnace. When continuously annealing, temperatures of about 450°F to about 1200°F may be employed with annealing times of about five minutes to about 1/10,000 of a minute. Generally, however, continuous annealing temperatures and times may be adjusted to meet the requirements of the particular overall processing operation so long as the desired tensile strength is achieved. In a batch annealing operation, a temperature of approximately 400°F to about 750°F is employed with residence times of about thirty (30) minutes to about twenty-four

(24) hours. As mentioned with respect to continuous annealing, in batch annealing the times and temperatures may be varied to suit the overall process so long as the desired tensile strength is obtained. Simply by way of example, it has been found that the following tensile strengths in the present aluminum wire are achieved with the listed batch annealing temperatures and times.

*TABLE I*

| *TENSILE STRENGTH* | *TEMPERATURE* | *TIME* |
|---|---|---|
| 12,000 to 14,000 | 650°F | 3 hours |
| 14,000 to 15,000 | 550°F | 3 hours |
| 15,000 to 17,000 | 520°F | 3 hours |
| 17,000 to 22,000 | 480°F | 3 hours |

During the continuous casting of this alloy, a substantial portion of the iron present in the alloy precipitates out of solution as iron aluminum intermetallic compound ($FeAl_3$). Thus, after casting, the bar contains a dispersion of $FeAl_3$ in a supersaturated solid solution matrix. The supersaturated matrix may contain as much as 0.17 weight percent iron. As the bar is rolled in a hot-working operation immediately after casting, the previously precipitated $FeAl_3$ particles are broken up and dispersed throughout the matrix and further $FeAl_3$ particles are precipitated in small size, all of which inhibit large cell formation. When the rod is then drawn to its final gauge size, without intermediate anneals, and then aged in a final annealing operation, the tensile strength, elongation and bendability are increased due to the small cell size and the additional pinning of dislocations by preferential precipitation of $FeAl_3$ on the dislocation sites. Therefore, new dislocation sources must be activated under the applied stress of the drawing operation and this causes both the strength and the elongation to be further improved.

The properties of the present aluminum alloy wire are significantly affected by the size of a majority of the $FeAl_3$ particles in the matrix. Coarse precipitates reduce the percent elongation and bendability of the wire by enhancing nucleation and, thus, formation of large cells which, in turn, lowers the recrystallization temperature of the wire. Fine precipitates improve the percent elongation and bendability by reducing nucleation and increasing the recrystallization temperature. Grossly coarse precipitates of $FeAl_3$ cause the wire to become brittle and generally unusable. Coarse precipitates have a particle size of about 2,000 angstrom units and fine precipitates have a particle size of below 2,000 angstrom units.

A typical alloy No. 12 AWG wire of the present invention has physical properties of 16,000 psi tensile strength, ultimate elongation of twenty percent (20%), conductivity of sixty-one percent (61%) IACS, and bendability of thiry (30) bends to break. Ranges of physical properties generally provided by No. 12 AWG wire prepared from the present alloy include tensile strengths of about 12,000 to about 22,000 psi, ultimate elongation of about forty percent (40%) to about five percent (5%), conductivities of about sixty-one percent (61%) to about sixty-three percent (63%) and number of bends to break of about forty-five (45) to ten (10).

When preparing particular end products, adjustments in the processing steps may be effected and additional steps may be performed. Thus, when preparing a solid insulated conductor, the continuously prepared rod is processed in a reduction operation designed to produce continuous wire of a gauge between 0000 gauge AWG (corresponding to a cross-sectional diameter or greatest perpendicular distance between parallel faces of about 0.460 inches) and 40 gauge AWG (corresponding to a cross-sectional diameter or greatest perpendicular distance between parallel faces of about 0.0031 inches). Following annealing, the solid aluminum alloy conductor is continuously insulated in a standard continuous insulating operation. A typical insulating operation comprises passing the solid conductor through an extrusion head. As the conductor passes through an extrusion head, a continuous thermoplastic coat of insulation is generated around the conductor. The coated conductor is then cooled in the air or by contact with a cooling bath. The insulating material should be one which is capable of insulating the solid conductor and the material should be of a thickness sufficient to insulate the solid conductor and withstand the physical hazards associated with solid insulated conductors. Typical thicknesses of insulation are between about 1/64ths of an inch and 3/64ths of an inch. A preferred thermoplastic insulating material is poly (vinyl chloride), but other coatings such as neoprene, polypropylene and polyethylene may also be employed.

A typical No. 12 AWG solid wire, which may be subsequently insulated to produce a solid insulated conductor using wire in accordance with the present invention, has physical properties of 16,000 psi tensile strength, ultimate elongation of twenty percent (20%), conductivity of sixty-one percent (61%) IACS, and bendability of thirty (30) bends to break. Ranges of physical properties generally provided by a suitable No. 12 AWG solid wire prepared from the present alloy include tensile strengths of about 13,000 to about 22,000 psi, ultimate

elongations of about thirty-five percent (35%) to about five percent (5%), conductivities of about sixty-one percent (61%) to about sixty-three percent (63%), and number of bends to break of about forty-five (45) to ten (10). Preferred wires for use in the present invention have a tensile strength of between 14,000 and 18,000 psi, and ultimate elongation of between thirty percent (30%) and fifteen percent (15%), a conductivity of between sixty-one percent (61%) and sixty-three percent (63%) and number of bends to break of between forty (40) and fifteen (15).

When preparing an insulated telephone cable, the continuously prepared rod is processed in a reduction operation designed to produce continuous wire of a gauge between No. 12 AWG (cross-sectional diameter or greatest perpendicular distance between parallel faces of 0.081 inches) and No. 30 AWG (cross-sectional diameter or greatest perpendicular distance between parallel faces of 0.0100 inches). Following annealing, the aluminum alloy wire is continuously insulated in a standard continuous insulating operation. A typical insulating operation comprises passing the wire through an extrusion head. As the wire passes through the head, a continuous thermoplastic coat of insulation is generated around the conductor. The coated conductor is then cooled in the air or by contact with a cooling bath. The insulating material should be one which is capable of insulating the wire and the material should be of a thickness sufficient to insulate the wire and withstand the physical hazards associated with the processing of the wire into a telephone cable. Typical thicknesses of insulation are between about 0.001 inches and 0.20 inches. A preferred insulating material is polyethylene, but other coatings such as neoprene, polypropylene and polyvinyl chloride may also be employed.

After insulation is applied to the individual wires, two or more of the insulated wires are brought together and twisted as a pair. These pairs may then be cabled into groups and these groups may be subsequently cabled into larger groups or cables. These groups or cables are then fed through a second extrusion head where an outer sheath of insulation is applied around the individually insulated wires. Alternatively, the groups or cables may be wrapped with a thin sheet or tape of plastics material prior to application of the outer sheath of insulation. As the insulated telephone cable emerges from the second extrusion head, it is cooled in the air or by contact with a cooling bath. The exterior insulation material is, preferably, polyethylene with other thermoplastic materials such as polypropylene, polyvinyl chloride and neoprene being suitable. The finished telephone cable may be additionally sheathed or armored in conventional fashion, if such is desired. A typical No. 18 AWG aluminum alloy wire suitable for use in the telephone cable of the present invention has physical properties of 17,000 psi tensile strength, ultimate elongation of fourteen percent (14%) and conductivity of sixty-one percent (61%) IACS. Ranges of physical properties generally provided by a suitable No. 18 AWG wire prepared from the present alloy include tensile strengths of about 13,000 to about 22,000 psi, ultimate elongations of about forty percent (40%) to about five percent (5%) and conductivities of about sixty-one percent (61%) to about sixty-three percent (63%). Preferred wires have a tensile strength of between 16,000 and 18,000 psi, an ultimate elongation of between twenty percent (20%) and ten percent (10%) and a conductivity of between sixty-one percent (61%) and sixty-three percent (63%).

When preparing an insulated magnet wire, the continuously prepared rod is processed in a reduction operation designed to produce continuous wire of a guage between 8 gauge AWG (cross-sectional diameter or greatest perpendicular distance between parallel faces of 0.128 inches) and 40 gauge AWG (cross-sectional diameter or greatest perpendicular distance between parallel faces of 0.0031 inches). The unannealed rod (i.e., as rolled to f temper, which may be defined as the temper of the aluminum rod as it leaves the rolling mill) is cold-drawn through a series of progressively constricted dies, without intermediate anneals, to form a continuous wire of desired diameter. If a cross-sectional shape other than round is desired, the drawn wire may be worked to a proper shape by cold-rolling or further drawing through appropriately shaped rollers or dies to produce the shaped wire. Typical cross-sectional shapes other than round are square and rectangular.

Following annealing, the aluminum alloy wire is continuously insulated in a standard magnet wire continuous insulating operation. A typical insulating operation comprises passing the solid conductor through a bath of enamel. As the conductor passes through the bath, a continuous insulating enamel coat is applied around the conductor. The coated conductor is then baked in a continuous furnace. The insulating enamel should be one which is capable of insulating the solid conductor and the enamel should be of a thickness sufficient to insulate the solid conductor and withstand the physical hazards associated with winding of magnet wire. The preferred insulating material is an enamel

such as the oleoresinous type, but other coatings such as fabrics, polyethylene, polypropylene, poly (vinyl chloride), polyurethanes, epoxies, a polyvinyl formal resin, and an overcoat of nylon, a urethane modified polyvinyl formal resin, an acrylic resin, a polyurethane base and a nylon overcoat, a modified polyester base with a linear polyester overcoat, a polyimide resin, cotton yarn and polyesters may also be employed. Typically, thermoplastic materials are applied by means of an extrusion head which coats the conductor with the thermoplastic material as the conductor moves through the head.

A typical No. 12 AWG solid insulated magnet wire of the present invention is prepared from a solid wire which has physical properties of 16,000 psi tensile strength, ultimate elongation of twenty-five percent (25%), conductivity of sixty-one percent (61%) IACS, and bendability of thirty (30) bends to break. Ranges of physical properties generally provided by a suitable No. 12 AWG wire prepared from the present alloy include tensile strengths of about 12,000 to about 17,000 psi, ultimate elongations of about forty percent (40%) to about fifteen percent (15%), conductivities of about sixty-one percent (61%) to about sixty-three percent (63%), and number of bends to break of about forty-five (45) to about fifteen (15). Preferred wires suitable for use in the present invention have a tensile strength of between 13,000 and 15,000 psi, an ultimate elongation of between thirty-five percent (35%) and twenty-five percent (25%), a conductivity of between sixty-one percent (61%) and sixty-three percent (63%) and number of bends to break of between thirty-five (35) and twenty (20).

When preparing a multi-filament conductor, the continuously prepared rod is processed in a reduction operation designed to produce continuous, individual filaments of wire of a gauge between 0000 gauge AWG cross-sectional diameter or greatest perpendicular distance between parallel faces of 0.460 inches) and 40 gauge AWG (cross-sectional diameter or greatest perpendicular distance between parallel faces of 0.0031 inches).

Following annealing, the individual filament of wire is stranded with other similarly produced alloy wires to produce a multi-filament stranded conductor. The stranded conductor is then continuously insulated in a standard continuous insulating operation. A typical insulating operation comprises passing the stranded conductor through an extrusion head. As the conductor passes through the head, a continuous thermoplastic coat of insulation is generated around the conductor. The coated conductor is then cooled in the air or by contact with a cooling bath. The insulating material should be one which is capable of insulating the multi-filament conductor and the material should be of a thickness sufficient to insulate the conductor and withstand the physical hazards associated with stranded insulated conductors. Typical thicknesses of insulation are between about .001 of an inch and .400 of an inch. A preferred thermoplastic insulating material is poly (vinyl chloride), but other coatings such as neoprene, rubber, polyethylene, polypropylene and cross-linked polyethylene may be employed.

A typical individual No. 12 AWG solid insulated strand, which is subsequently grouped into a multi-filament conductor, has physical properties of 16,000 psi tensile strength, ultimate elongation of twenty percent (20%), conductivity of sixty-one percent (61%) IACS, and bendability of thirty (30) bends to break. Ranges of physical properties generally provided by a suitable No. 12 AWG strand prepared from the present alloy include tensile strengths of about 13,000 to about 22,000 psi, ultimate elongations of about thirty-five percent (35%) to about five percent (5%), conductivities of about sixty-one percent (61%) to about sixty-three percent (63%), and number of bends to break of about forty-five (45) to ten (10). Preferred strands for use in the present conductor have a tensile strength of between 13,000 and 18,000 psi, an ultimate elongation of between thirty percent (30%) and fifteen percent (15%), a conductivity of between sixty-one percent (61%) and sixty-three percent (63%), and number of bends to break of between forty (40) and fifteen (15).

The individual strands of wire formed from the present alloy may be grouped together prior to the insulation thereof in several formations including concentric stranding, bunch stranding, parallel stranding and rope lay stranding. In concentric stranding, a strander conventionally strands in a helical fashion six or more wire strands about a central wire strand. The stranded unit is then passed through the extrusion head of an extruder where insulation is applied around the outer surfaces of the stranded unit.

In bunch stranding, individual wires are brought together with some twisting of the unit of wires and insulation is applied around the outer surfaces of the stranded unit.

In parallel stranding, individual wires are brought together in parallel fashion with no twisting of the unit of wires and insulation is applied around the outer surfaces of the stranded unit.

In rope lay stranding, individual uninsulated concentrically stranded or bunched cables are concentrically stranded or bunched into a composite cable. Insulation is then applied to the outer surfaces of the composite cable as a whole.

It has been found that stranding and insulating wires of the present alloy yields a cable which has improved bendability over solid insulated conductors, and, in addition, has improved bendability over stranded and insulated EC alloy wire.

Several advantages are obtained by preparing the present aluminum alloy with an iron content of between 0.30 and less than 0.45 weight percent. Of significant importance is the fact that the wire product will achieve an annealed condition more quickly and at a lower temperature than products containing more iron. In addition, it is of particular significance that by using an amount of iron within the present range, it is possible to use more silicon and thereby obtain an alloy with excellent physical properties and acceptable electrical conductivity. It was felt in the past that as much as 0.15 weight percent silicon could be used to obtain a superior product only when the iron content was as high as approximately 0.95 weight percent. It has now been discovered that as much as 0.15 weight percent silicon may be used with as little as 0.30 weight percent iron and an excellent product will be obtained.

It should be understood that the present invention at least in part concerns insulated aluminum alloy multi-filament conductors the filaments consisting of wires in accordance with the invention. Particular examples of specific insulated multi-filament conductors or cables include building cable, auto ignition and primary cable, underground building cable, battery cable and battery cable ground wire, aircraft cable, harness cable, neon sign cable, radio hookup cable, fire alarm and burglar alarm cable, fixture cable, control cable, machine tool cable, enunciator cable, heater cord, lamp cord, flexible electric cord, welding and mining cable, locomotive cable, armor cable, cable with a flexible cross-link polyolefin insulation, service drop, braided cable, appliance cable, and composite cable of aluminum or copper strands about a steel or aluminum alloy core.

For the purpose of clarity and unless there is a contrary indication in the specification, the following terminology used in this application is explained as follows:

Rod—A solid product that is long in relation to its cross-section. Rod normally has a cross-section of between three inches and 0.375 inches.

Wire—A solid wrought product that is long in relation to its cross-section, which is square or rectangular with sharp or rounded corners or edges, or is round, a regular hexagon or a regular octagon, and whose diameter or greatest perpendicular distance between parallel faces is between 0.375 inches and 0.0031 inches.

It will be understood from the above that the conductivity of the rod and the conductivity of the wire are quite different. We have found that the conductivity of the rod should be less than 61% IACS while the conductivity of the wire should be more than 61% IACS. A bar is first cast and then hot rolled to rod form preferably approximately ½ inch in diameter and then the rod may be cold drawn to wire of several gauges so that the rod is an intermediate product in the production of the wire. We have found that if the conductivity of the rod is greater than 61% IACS then the wire produced from the rod will have undesirable physical properties and conversely we have found that only when the rod has a conductivity of less than 61% IACS will an acceptable wire be produced. This discovery has proved to be very significant since previously it was felt in the industry that the rod should have a conductivity greater than 61% IACS in order that the wire made from the rod should have a conductivity greater than 61% IACS. We have now found that with our special alloy wire, which we call "Triple E Aluminium Alloy" that the conductivity will increase considerably during the annealing or partial annealing operation so that the conductivity of the wire will increase to a figure greater than 61% IACS after annealing or partial annealing when the wire had a conductivity less than 61% IACS before annealing.

In one specific and preferred process in accordance with a feature of the invention of preparing an aluminum wire having an electrical conductivity of at least 61% IACS the process comprises the steps of

a. Alloying from 0.30 to less than 0.45 weight percent iron, 0.015 to 0.15 weight percent silicon, impurities, and the remainder aluminum, the ratio of iron content to silicon content being at least 1.99 to 1;

b. Casting the alloy into a bar;

c. Hot-rolling the bar to form rod having a conductivity of less than 61% IACS;

d. Drawing the rod with no preliminary or intermediate anneals to form wire having a conductivity of less than 61% IACS,

e. Annealing or partially annealing the wire by batch annealing at a temperature of 400°F to 750°F for a time of 24 hours to 30 minutes or continuous annealing at a temperature of 450°F to 1200°F for a time of 5 minutes to one ten thousandth of

a minute to obtain a wire having a conductivity of at least 61% IACS and substantially evenly distributed $FeAl_3$ inclusions of a particle size of less than 2.000 angstrom units.

While this invention has been described in detail with particular reference to preferred embodiments thereof, it will be understood that variations and modifications can be effected within the scope of the invention as defined in the appended claims.

WHAT WE CLAIM IS:—

1. Wrought aluminum alloy wire having a minimum conductivity of sixty-one percent IACS consisting essentially of from 0.30 to less than 0.45 weight percent iron; 0.015 to 0.15 weight percent silicon; from 0.0001 to less than 0.05 weight percent each of trace elements selected from the group consisting of vanadium, manganese, zinc, boron, and titanium, and the remainder aluminum, said alloy containing from 0.004 to 0.15 total weight percent trace elements and substantially evenly distributed $FeAl_3$ inclusions having a particle size of less than 2000 Angstrom units.

2. Aluminum alloy wire having a minimum conductivity of sixty-one percent IACS containing substantially evenly distributed $FeAl_3$ inclusions in a concentration produced by the presence of 0.30 to less than 0.45 weight percent iron in an alloy mass consisting essentially of 0.015 to 0.15 weight percent silicon; conventional impurities; and the remainder aluminum; a majority of said $FeAl_3$ inclusions having a particle size of less than 2,000 angstrom units.

3. A process for preparing an aluminum alloy wire according to claim 1 or 2 having an electrical conductivity of at least 61 percent IACS comprising the steps of:

a. Alloying from 0.30 to less than 0.45 weight percent iron, 0.015 to 0.15 weight percent silicon, and from 0.0001 to 0.05 weight percent each of trace elements selected from the group consisting of vanadium, manganese, zinc, boron and titanium, and the remainder aluminum; the total weight percent of trace elements being 0.004 to 0.15 weight percent;

b. Casting the alloy into a continuous bar in a moving mold formed by a groove in the periphery of a casting wheel and an endless belt lying adjacent the groove along a portion of the periphery of the wheel;

c. Hot-working the bar substantially immediately after casting while the bar is in substantially that condition as cast by rolling the bar to obtain a continuous aluminum alloy rod having a conductivity of less than 61% IACS;

d. Drawing the rod with no preliminary or intermediate anneals to form wire having a conductivity of less than 61% IACS; and

e. Annealing or partially annealing the wire to obtain wire having a conductivity of at least 61% IACS and $FeAl_3$ inclusions with a particle size of less than 2,000 angstrom units.

4. A process according to Claim 3 wherein step (e) comprises batch annealing or partially batch annealing the wire.

5. A process for preparing an aluminum alloy wire according to claim 1 or 2 having an electrical conductivity of at least 61 percent IACS comprising the steps of:

a. Alloying from 0.30 to less than 0.45 weight percent iron, 0.015 to 0.15 weight percent silicon, and from 0.0001 to 0.05 weight percent each of trace elements selected from the group consisting of vanadium, manganese, zinc, boron and titanium; and the remainder aluminum; the total trace element content being from 0.004 to 0.15 weight percent;

b. Continuously casting the alloy into a continuous bar;

c. Continuously rolling the bar in substantially that condition in which it was cast into a bar to form a continuous rod;

d. Drawing the rod with no preliminary or intermediate anneals to form wire having a conductivity of less than 61% IACS; and

e. Annealing or partially annealing the wire to obtain a wire having a conductivity of at least 61% IACS.

6. Process for preparing an aluminum alloy rod for subsequent use in the preparation of an aluminum alloy wire according to claim 1 or 2 having a minimum conductivity of 61% IACS comprising the steps of:

a. Alloying from 0.30 to less than 0.45 weight percent iron, about 0.015 to about 0.15 weight percent silicon, and from 0.0001 to 0.05 weight percent each of trace elements selected from the group consisting of vanadium, manganese, zinc, boron and titanium; and the remainder aluminum; the total weight percent of trace elements being from 0.004 to 0.15 weight percent;

b. Casting the alloy into a continuous bar in a moving mold formed by a groove in the periphery of a casting wheel and an endless belt lying adjacent the groove along a portion of the periphery of the wheel; and

c. Hot-working the bar substantially immediately after casting while the bar is in substantially that condition as cast by rolling the bar to obtain a continuous aluminum alloy rod having a conductivity of less than 61 percent IACS, said rod having been subjected to no preliminary or

intermediate anneals.

7. A process for preparing an aluminum alloy wire according to claim 1 or 2 having an electrical conductivity of at least 61 percent IACS comprising the steps of:

a. Alloying from 0.30 to less than 0.45 weight percent iron, 0.015 to 0.15 weight percent silicon, impurities, and the remainder aluminum, the ratio of iron content to silicon content being at least 1.99 to 1;

b. Casting the alloy into a bar;

c. Hot-rolling the bar to form rod having a conductivity of less than 61% IACS;

d. Drawing the rod with no preliminary or intermediate anneals to form wire having a conductivity of less than 61% IACS; and

e. Annealing or partially annealing the wire by batch annealing at a temperature of 400°F to 750°F for a time of 24 hours to 30 minutes or continuous annealing at a temperature of 450°F to 1200°F for a time of 5 minutes to one ten thousandth of a minute to obtain a wire having a conductivity of at least 61% IACS and substantially evenly distributed $FeAl_3$ inclusions of a particle size of less than 2,000 angstrom units.

8. A process for preparing an aluminum wire according to claim 1 or 2 having an electrical conductivity of at least 61% IACS comprising the steps of:

a. Alloying from 0.30 to less than 0.45 weight percent iron, 0.015 to 0.15 weight percent silicon, impurities, and the remainder aluminum, the ratio of iron content to silicon content being at least 1.99 to 1;

b. Continuously casting the alloy into a continuous bar;

c. Continuously rolling the bar in substantially that condition in which it was cast into a bar to form a continuous rod having a conductivity of less than 61% IACS.

d. Drawing the rod with no preliminary or intermediate anneals to form wire having a conductivity of less than 61% IACS; and

e. Annealing or partially annealing the wire to obtain a wire having a conductivity of at least 61% IACS and substantially evenly distributed $FeAl_3$ inclusions of a particle size of less than 2,000 angstrom units.

WITHERS & ROGERS,
Chartered Patent Agents,
148/150 Holborn,
London, E.C.1.

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